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Research Article

CARBON ION INDUCED CONDUCTIVITY OF POLYETHYLENE NAPHTHALATE (PEN)

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ABSTRACT
The effects on the conductivity of Polyethylene Naphthalate, PEN pristine and irradiated with Carbon ions (85MeV) of different fluences have been analyzed using heavy ion irradiation technique. The analyses indicate that electronic conduction in the polymer is via hopping process.

Keywords*: *Polymers, Dielectric Properties, Thin Films, Carbon-Ions, PEN

INTRODUCTION
Humans have taken benefit of the flexibility of polymers for centuries. The fabrication cost of polymers is low and the executable of polymers is quite effortless. Poly (ethyethylene-2, 6-naphthalene dicarboxylate) (PEN) is an aromatic polyester that demonstrates high-quality physical and chemical properties. PEN is developed by condensation polymerization of 2, 6- naphthalene dicarboxylic acid and ethylene glycol (Mancik, 1967; Cakmak *et al.*, 1990; Desai and Wilkes, 1974). There has, however, been increasing concern in its commercial utilization, since new indications that the dicarboxylic acid monomer may become available in large-scale quantities. PEN molecules contain naphthalene rings, hence, are stiffer than those of poly (ethylene terephthalate) (PET).
Aromatic polymers with benzene rings either in the main chain or on the side (e.g., polycarbonate) are in general radiation resistant (Cheng and Kerluke 2003). Moreover, radiation effects on dielectric properties of polymers have been also studied earlier (Darwish *et al.*, 2005; Kim *et al.*, 2000; Boudou *et al.*, 2001). The study of different properties of PEN has been depicted in number of research papers (Cheng and Wunderlich, 1988; Buchner *et al.*, 1989; Murakami *et al.*, 1996).
The present work deals with the studies of the conductivity of PEN polymer irradiated carbon ions (85 MeV). The study furnishes data about the unalterable changes triggered in properties of polyethylene naphthalate, after Swift heavy ion irradiation.

MATERIALS AND METHODS
The specimens of Polyethylene naphthalate (PEN) in the form of flat polished thin films (25µm) were procured from Good Fellow Ltd. (England). These films were used as-received form without any further treatment in the size of 1 cm x 1 cm. The samples were mounted on the sliding ladder and irradiated with Carbon (85MeV) ions beam using 15 UD pelletron facility for the general purpose scattering chamber (GPSC) under vacuum of ~10^{-6} Torr at Inter-University Accelerator Center, New Delhi. The ion range, electronic energy loss and nuclear energy loss of characterize carbon (85 MeV) ions in PEN polymer is ~185.97 (µm), 27.85eV/Å and 1.445 E-02 (eV/Å) respectively (Ziegler, 2008). The range of all ions is more than the thickness of polymer films. The ion beam fluence was varied from 1 x 10^{11} to 3 x 10^{12} ions cm^{-2}.
In order to expose the whole target area, the beam was scanned in the x-y plane. The beam current was kept low to suppress thermal decomposition and was supervised intermittently with a Faraday cup. Doses (Table 1) for the given fluence and studied ion type were calculated using the formula (Geiβ *et al.*, 1998) as given as:

$$\text{Dose} = 1.602 \times 10^{-10} \times \frac{1}{\rho} \times \frac{dE}{dx} \times \phi \qquad (1)$$

ϕ: Ion fluence, ρ: Density of polymer, $\frac{dE}{dx}$: Stopping power of ion

Table 1: Doses for Given Fluence of Silver Ion of PEN Polymer

S. no.	Polymer	Ion Fluence (Ions/cm^2)	Carbon (85 MeV) (kGy)
1.	PEN	Pristine	0.00
		1 x10^{11}	32.80
		1 x10^{12}	328.04
		3 x10^{12}	984.13

The Precision impedance analyzer 6500B is used to measure coductivity of pristine and irradiated samples of polyethylene naphthalate at room temperature in the frequency range 20Hz-1MHz.

RESULT AND DISCUSSION

The graph between log frequency and ac conductivity (logσ_{ac}) is plotted for pristine and ion irradiated samples (irradiated with 85 MeV Carbon ions) and is shown in Figure1. The substantial change is detected in the *ac* conductivity which may be assigned due to the formation of ion induced defects along the course of incoming ions. A large amount of energy is deposited along the trajectory of the ion, when swift heavy ions enter into the material. The major amount of ion's energy is lost due to the ionization and excitation of atoms and is named as electronic energy loss S_e. The remaining energy of ion is used for

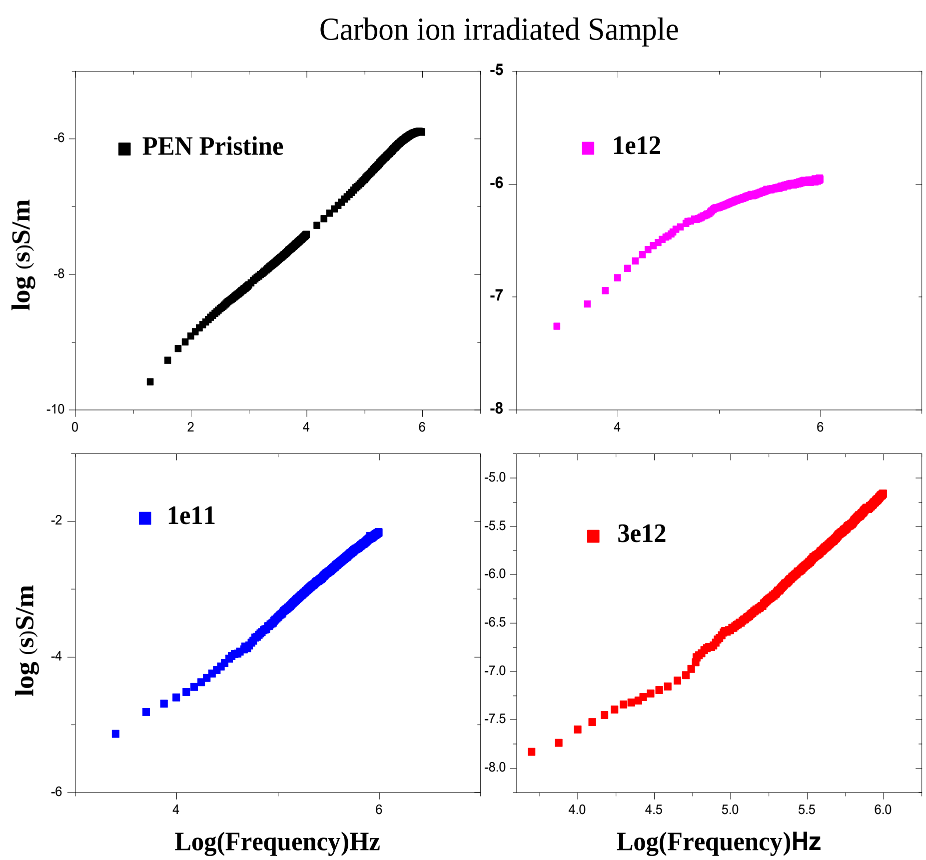

Figure 1: Conductivity Spectra of Poly Ethylene Naphthalate (PEN) Samples Irradiated with Varying Fluences of Carbon Ions

elastic and inelastic nuclear collisions and is named as nuclear energy losses S_n. Since, the electronic energy loss S_e is usually more prominent than nuclear energy loss S_n, thus there is formation of large number of disordered regions. With the increase in ion fluence, these disordered regions overlap and lead to formation of ion stimulated defects and causes a change in the *ac* conductivity. The linear relation of $\log\sigma_{ac}$ versus log frequency expresses that *ac* conductivity pursues the relation $\sigma_{ac}\alpha\ f^n$ where n is the frequency exponent and can be computed from the slope of straight lines of Figures 1.

The linear relation of *ac* conductivity with frequency and the value of $n<1$ depict for the electronic conduction via hopping process.

Conclusions

Specimens of Polyethylene naphthalate have been irradiated with 85 MeV Carbon ions at different fluencies in the range from 1 x 10^{11} to 3 x 10^{12} ions cm^{-2}. Irradiated PEN show a substantial change in the *ac* conductivity which may be due to the establishment of ion induced defects. The graph of log *ac* conductivity is proportional to $f^{\,n}$ in pristine and irradiated PEN with a slope $n<1$ which indicates that electronic conduction happens through hopping process.

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